Sediment Transport by Internal Waves in EUROSTRATAFORM

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LONG-TERM GOALS

This project investigates the role that internal waves might have in sediment transport in the EUROSTRATAFORM project. The overall long-term project goal is to determine the modes and mechanisms of transport of bottom and suspended sediment by internal waves. The specific goal of this work is to use available and newly acquired data on internal waves and density structure in the Adriatic Sea to investigate internal wave effects on sedimentation.

OBJECTIVES

- Evaluate the role of internal waves in resuspending and transporting sediment on the shallow sections of the Adriatic continental shelf off central Italy (water depths < 100 m).

- Develop relationships for estimating internal wave-induced bottom stresses that can be applied to sediment transport calculations.

APPROACH

This project is primarily focused on the interaction of internal waves and the seabed. The approach is similar to the research developed in STRATAFORM (Cacchione, et al, 2002). We are using temperature and current data that was obtained during EUROSTRATAFORM field experiments to estimate internal wave effects on sedimentation. Expressions for internal wave induced bottom stresses that can be used to predict sediment entrainment by internal waves are under development. A second task was to assist in planning and coordination of field experiments in EUROSTRATAFORM study areas.

This effort has two principal research tasks: (1) development of mathematical expressions for bottom stress by internal waves over sloping bottoms; (2) analysis of density profiles and time-series temperature and current measurements to investigate internal wave and sediment dynamics in the study areas.

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WORK COMPLETED

- Characteristic angles (i.e., group velocity vector directions) have been calculated for internal waves of various frequencies using Brunt Vaisala frequencies determined from density profiles.
- Spectral analyses of velocity and temperature data from PASTA have been completed. The data were obtained on a mooring deployed in about 50 m water depth off Pescara, Italy by Spanish scientists. In particular, analysis of velocity and temperature data showed energetic motions at near-inertial and higher internal wave frequencies.
- An expression for bottom stress due to shoaling high frequency internal waves has been developed and applied to the PASTA region.
- Analysis of suspended sediment transport by near-inertial internal waves has been completed.

RESULTS

The effects of internal waves and tides on transport of bottom and suspended sediment are poorly understood. We have approached this problem both theoretically and using new temperature and current data collected during the first EUROSTRATAFORM field experiment in the Adriatic study area. In last year's annual report (Cacchione, 2005) we reported on high frequency internal waves observed in the temperature and current profiles. These data were collected on the southernmost measurement line in the PASTA region (Fig. 1).

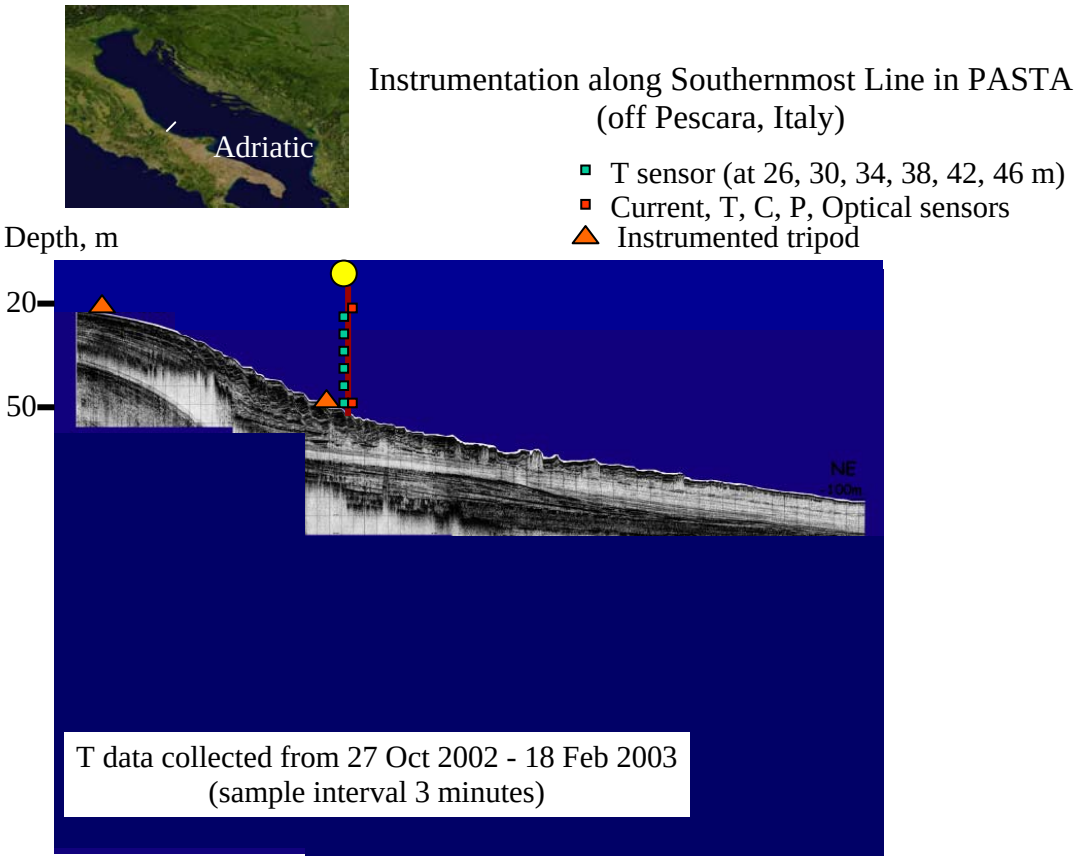

Fig. 1. Location of mooring and instrumented tripods on the southernmost measurement transect in the PASTA region. High-resolution seismic x-section from F. Trincardi (pers. comm.). Note the large bedforms along the slope deeper than about 30 m.

We obtained time-series temperature data at six levels along the mooring that was deployed by Spanish scientists the southernmost transect off Pescara, Italy (Fig. 1). The data were collected at 3 minute intervals in 26, 30, 34, 38, 42 and 46 m water depths from 27 Oct 2002 – 18 Feb 2003. Power spectra show a general increase in energy in the IW band at frequencies between N and f, but also contain curious peaks at lower frequencies (Cacchione, 2005). The energy peaks at about 40, 50 and 72 hours possibly represent motions caused by internal seiche in the Adriatic Basin. Preliminary estimates of internal seiche periods assuming a cross-basin length scale of 100 km indicate periods of 40-70 hours for 2 or 3 nodes. Continued analysis of these low frequency energy peaks in underway.

On the PASTA shelf and upper slope region, bottom slopes are typically gentle, ~ 0.05^o to 0.3^o (γ ~ 0.0008 to 0.005). In this region the inertial frequency f ~ 0.056 cph. Values of Brunt Vaisala frequency N determined profiles of T and salinity were in the range of 2 cph < N < 16 cph (quite high N at the seasonal pycnocline at 10-50 m depths).

In the last year's annual report we showed that near-inertial IWs were critical or near-critical over the slopes in this region. The near-inertial period T_f of about 17.8 hr is critical along a slope of ~ 0.07^o (or γ ~ 0.001). The temperature and current meter data from the mooring that was deployed along the southern transect in the PASTA experiment (at ~ 50 m water depth) indicate episodic intense near-inertial internal motions, likely caused by low pressure atmospheric events with high surface winds.

Our initial analysis of the intensified near-inertial IW wave events suggests a 3 to 5-fold increase in near-bottom bottom velocities. The current and temperature data show some evidence of this intensification. Inertial period currents can be easily observed in the current data shown in Fig. 2. These currents might be important for transport of fine sediment in the PASTA region. The direction of strongest transport (determined from the two velocity components) is strongly oblique to the slope toward the southwest. This transport would augment the mean southwestward drift of fine sediment in the region, and contribute to the growth of the modern sediment deposit along the shelf and upper slope.

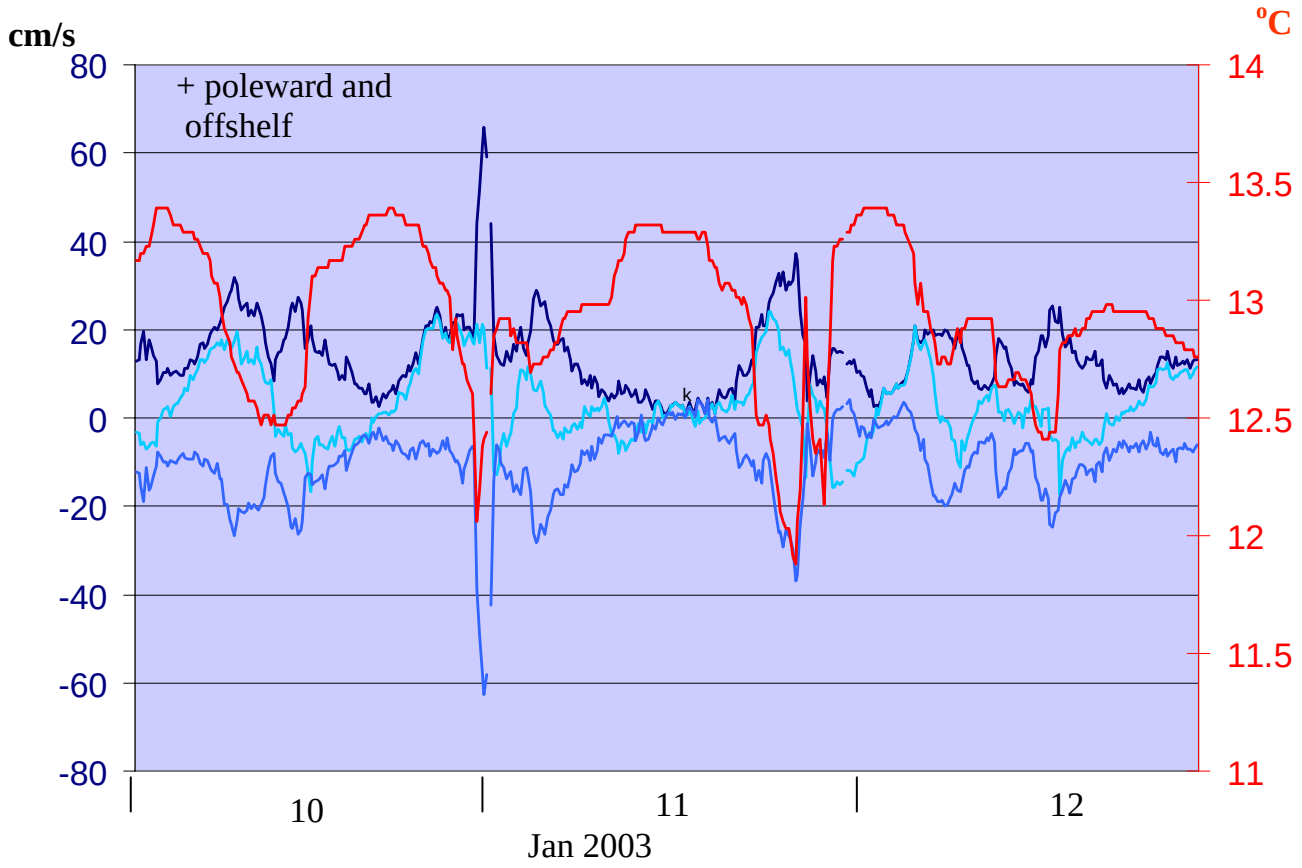

Fig. 2. Near bottom currents at the PASTA mooring shown in Fig. 1. Total current speed in dark blue; Along-shelf current speed in medium blue; cross-shelf current speed in light blue. Temperature in red.

IMPACT/APPLICATIONS

Internal wave-induced bottom stresses might have a major influence on controlling erosion and deposition on shelves and slopes in the oceans and in the Mediterranean Sea. Both high frequency and near-inertial IWs might be important processes for entraining bottom materials and transporting fine sediment. They might also contribute to the formation and modification of bedforms that have been observed along the Adriatic shelf and on the outer shelf in the Gulf of Lyons.

Also, if high frequency internal waves intermittently shoal and break along the seafloor in the seasonal pycnocline, erosion and resuspension of bottom sediment might occur. This process could lead to dispersal of sediment, and generation of turbid bottom layers.

TRANSITIONS

This work has applications for modeling of formation of sedimentary strata and structures on continental shelves. It may also have implications for sedimentation on certain continental shelves where turbulent shears from surface waves and other currents are relatively low (as compared with internal wave effects). The results and model can be integrated into more comprehensive sedimentation models that are under development by others (e.g., J. Syvitski and L. Pratson).

RELATED PROJECTS

The internal wave work is being done in close collaboration with other EUROSTRATAFORM investigators: Dr Pere Puig and Dr. Albert Palanques (both at Ciencies del Mar, Barcelona, Spain), Dr. Andrea Ogston (U. of Washington).

This project is closely related to those EUROSTRATAFORM projects investigating morphology and surface sedimentation on continental shelves. The work is related to projects led by L. Pratson (Duke University), C. Nittrouer, and A. Ogston (both at University of Washington), J. Syvitski (INSTARR, University of Colorado), and M. Steckler (Lamont-Doherty Geological Observatory).

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PUBLICATIONS

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